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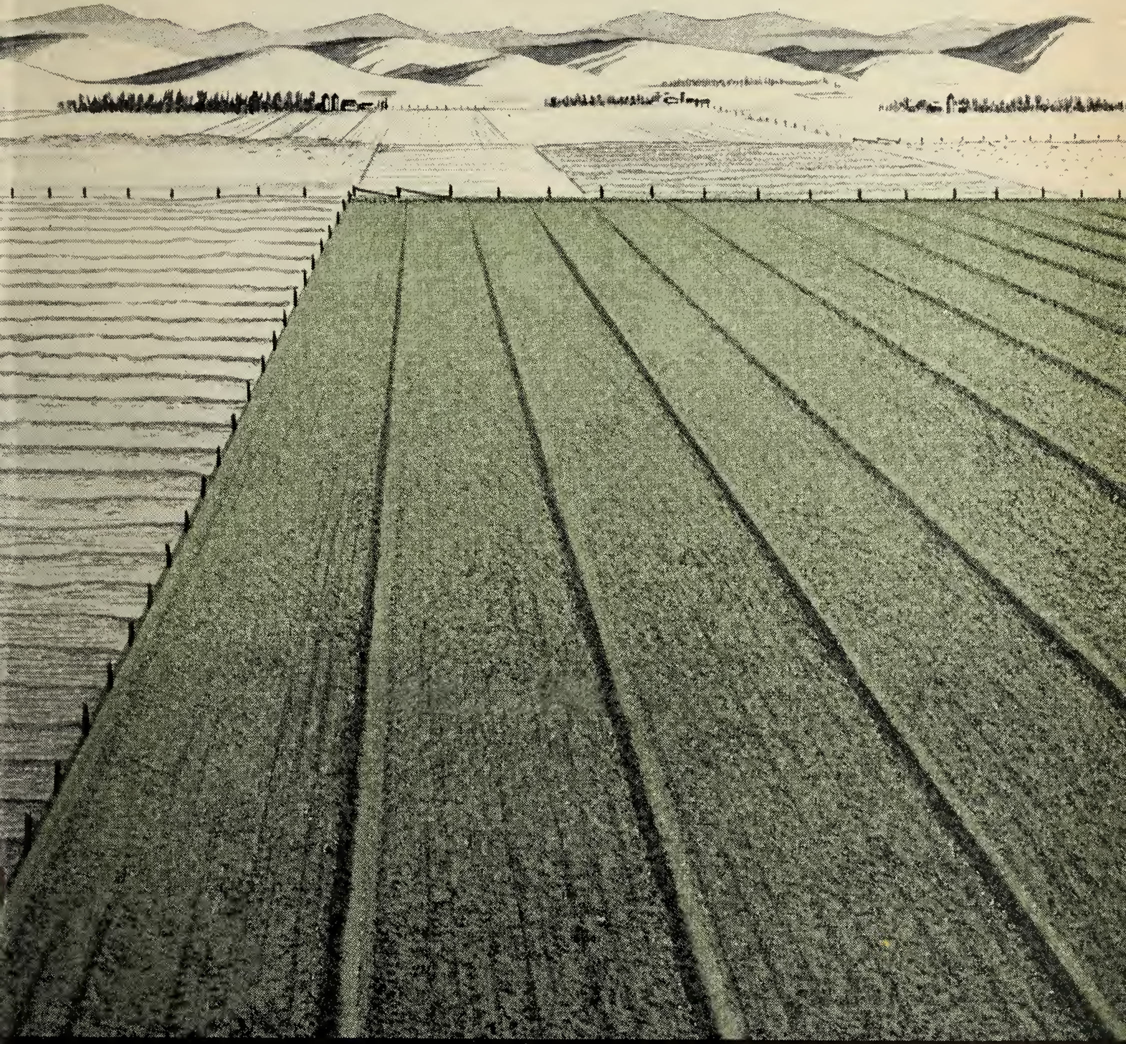
James C. Marr

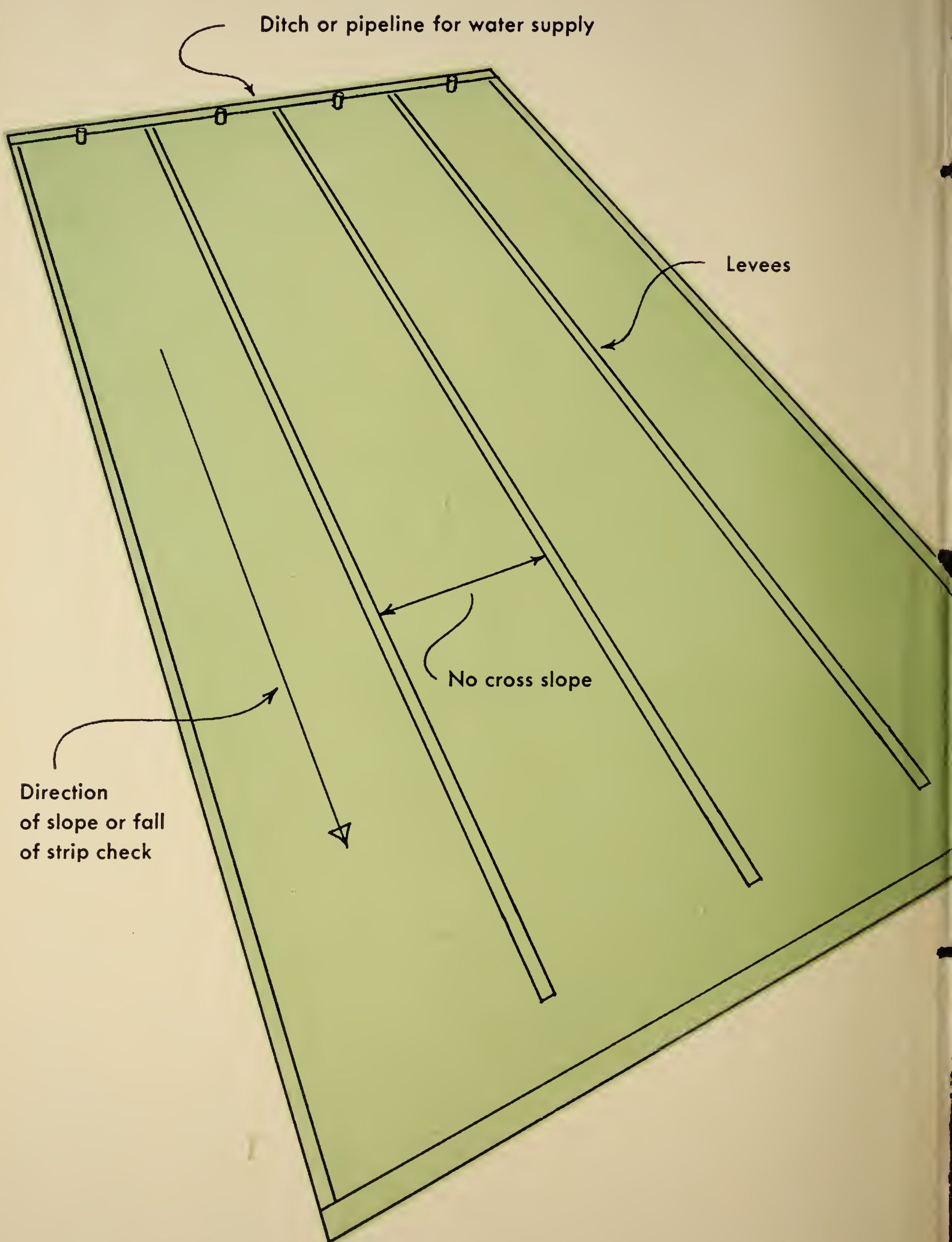
The BORDER METHOD OF IRRIGATION



CALIFORNIA AGRICULTURAL
Experiment Station
Extension Service

CIRCULAR 408

The BORDER METHOD



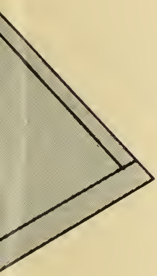
# of IRRIGATION

its Design, Construction, and Use in California

Border irrigation is the most popular method of applying water to close-growing crops, and sometimes to orchards, in the state of California.

The American Society of Agricultural Engineers describes border irrigation as ". . . a method applying water to land between parallel ridges or borders. The strips of land between adjacent borders have no cross slopes, but may have a grade in the direction of the irrigation."

The parallel ridges are usually called levees. The strips of land between the levees are usually called strip checks.



This circular tells how to design, construct, and use a border irrigation system efficiently, either for temporary or permanent facilities. It discusses and tells how to shape levees to allow for different uses to which they may be put. It discusses and recommends types of machinery that are best adapted to the various operations performed in constructing border systems. It gives some recommendations for the operation of a border system that will enable farmers to make the best use of their facilities.

The drawing on the left is probably oversimplified, but shows the main features of a typical border irrigation system—features that are discussed more thoroughly in this circular.

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In border irrigation, water is turned into the upper, or higher end of each strip check and allowed to move down the slope. While it may seem a simple matter to design such a system, the principles of design must first be mastered. But before anything else, you should decide whether you need a temporary or a permanent system.

TO DESIGN A GOOD SYSTEM
you need knowledge and skill

A temporary system warrants minimum outlay of time and money

Temporary border-irrigating systems are used in cultivated orchards, for pre-irrigating land which is to be planted in row crops, and for watering early-maturing annual crops.

After grading and cultivating the land, you can construct a satisfactory system for temporary use by making a single trip with a ridger or a border disk.

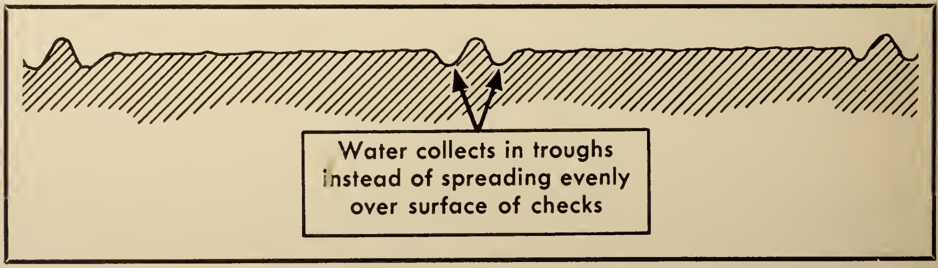
Levees formed by this method are narrow and sharp crested. They would not remain serviceable if they were repeatedly run over by farm machinery, as is often necessary in an alfalfa field. Furthermore, the ridger or border disk leaves a furrow or trough on either side of the levees, which should be dammed at regular intervals, in order to keep the water spread over the strip check. These conditions make it difficult to control the flow of water, and also require much extra labor during irrigation.

Nevertheless, the inconvenience and extra work involved are more than offset by the saving in time and expense that would be required for building up, and later flattening out, the more permanent type of levee.

A permanent system is needed for alfalfa

When perennial crops, such as alfalfa, clover, or pasture, are irrigated, the strip checks must last for years. Therefore, they should be built to insure the best possible use of water, with minimum labor necessary for operation and maintenance. To this end, the strip checks are prepared so that the irrigation water will spread evenly across them without the aid of cross dikes or furrows.

CROSS SECTION SHOWING A TEMPORARY BORDER SYSTEM



Levees should be substantial enough to stand the impact of harvesting equipment, or the trampling of livestock, and of a shape that will allow the water to wet all the way through them. Levees are arranged on the field to suit the requirements of the crop being handled.

Finally, the length of the strip checks should be so planned that when water is let into them, the soil will be wetted at all points to within at least 80 per cent of the same depth.

Type of soil is important in irrigating pasture. Because of the wide range in soil and topographic conditions that can be used for growing pasture, the border method is carried on under conditions peculiar to the demands of irrigated pasture.

Soil used for growing pasture usually consists of deep clay, or a shallow topsoil over hardpan. It absorbs water slowly. The grasses and legumes ordinarily planted for pasture will, therefore, develop shallow root systems. In order to keep the crop supplied with sufficient moisture, irrigation must be light and frequent.

Pasture land may be rougher and steeper than land suitable for most other border-irrigated crops. Here, then, the irrigation layout for pasture land usually serves only one purpose—to furnish water for the pasture—and other farm operations need not be considered.

Alfalfa has special needs. Alfalfa and other deep-rooted, close-growing perennial crops raised for hay or seed, require an irrigation layout designed to water deeply and to facilitate the harvest and removal of the crop.

Cross slopes and irrigation slopes are generally small. Strip checks should be as wide as possible to make them convenient for operating farm implements. Wide, low levees are usually desirable.

By way of identification—top photo shows a ridger; the center photo, a border disk; lower photo shows a temporary levee system with dams.

Ideal strip checks should have no cross slope

The surface crosswise of a strip must be such that as the irrigation stream enters the strip check and flows down the slope, it will completely cover the ground surface between the levees. Strip checks should be constructed flat in both directions, for approximately the first 30 feet next to the irrigation supply ditch, or pipe line.

A small cross slope is allowable. Since the depth of water in a strip check during an irrigation is at least 2 inches and may be as much as 5 inches, some departure from the 0.00 slope may occur. It is considered acceptable practice, for example, to disregard a cross slope of 0.2 foot per 100 feet, when border spacings range from 30 to 40 feet. This is an allowance per strip check of 0.06 to 0.08 foot, or, roughly, one inch.

When the cross slope exceeds this average amount it is advisable to level the strip checks individually by one of the methods described on page 14. Under these circumstances, the slope will be taken up by a difference in elevation on either side of each levee.

Difference in elevation has limits. Terraces in border-irrigated fields are a nuisance, and should be minimized as much as possible. The trouble they cause increases with their height. They become difficult to cross with farm machinery. Confining the water to individual strip checks, especially in rodent-infested fields, may become impossible. Finally, when the terraces are so high and so steep that they cannot be watered and cropped, they deteriorate into wastelands, and can become a liability of no small consequence.

A 0.2 to 0.3 foot drop between successive strip checks does not cause too much trouble. If that amount is exceeded, the land should first be benched or widely terraced, so that most or all of the cross slope is eliminated.

The same objections may be made to an occasional major terrace. Sometimes these may be avoided by grading out the excess cross slope over an entire field; or, when it is practical to do so, by locating the borders at right angles to the contours.

Sometimes it is possible to make widely spaced terraces less objectionable by locating them along drainage lines, access roads, or similar breaks in the cultivated area.

What is an irrigation slope?

An irrigation slope is commonly understood to be the amount of fall per unit length of strip check, expressed in feet fall per 100 feet of length, such as 0.5 foot per 100 feet; or in per cent, such as $\frac{0.5'}{100} \times 100 = 0.5$ per cent.

Land is usually leveled for irrigation as economically as possible; and, if conditions permit, the border system must be made to conform to the resulting irrigation and cross slopes.

Therefore, though irrigation slope is a very important factor in design, it cannot always be ideal. Adjustments to improve irrigation performance can be made, however, within slope limitations, by changing the size of the irrigation stream or the length or width of the strip check.

Slope limitations for alfalfa. The slope limitations for border-irrigated alfalfa are 0.15 per cent minimum and approximately 1.5 per cent maximum. A uniform slope ranging from 0.2 to 0.3 per cent is usually ideal.

The maximum slope that can be used depends on the erodability of the soil, the manner in which the crop can be started, and the spacing of the levees. Clay withstands erosion better than silt. A protective cover of young alfalfa started either by winter precipitation, sprinkling (see *Sprinkling for Irrigation*, Circular 388 of the California Agr. Exp. Sta.) or by

corrugation irrigation (see *The Corrugation Method of Irrigation,* U.S.D.A. Farmers' Bul. 1348), will prevent the serious erosion that would otherwise occur.

Narrow strip checks cut down erosion. Because the irrigation streams required to fill narrow strip checks are small, the water is less likely to channelize.

Thus, to irrigate a clay soil on a 1.5 per cent slope without serious erosion, a plant-covered surface and narrow strip checks of 20 feet would be required.

Slope limitations for pasture range from 0.15 to 0.5 per cent minimum, to about 4 per cent maximum. The minimum slope that can be safely used depends on the permeability of the soil profile. Irrigated pastures are usually planted on soils that either limit the amount or prevent the deep percolation of water.

If percolation is merely retarded and not completely stopped, the minimum slope may be 0.15 per cent. If percolation is virtually stopped by an impervious soil layer, the slope should be 0.5 per cent or more.

Slope aids drainage. A slowly permeable soil will drain internally and may, therefore, be irrigated on flat slopes. But a soil underlaid by impervious material at depths of a foot or less is easily waterlogged during irrigation, unless surface drainage is provided for by the use of somewhat steeper slopes. Poor drainage frequently results in the dying out of the crop, which is gradually replaced by watergrass and sedges.

Since permissible irrigation slopes are greater for pasture than for alfalfa, this problem of erosion may be a very real one. It can be met by the use of extra-narrow strip checks and smaller unit irrigation streams.

Uniform slopes used only when necessary. A uniform irrigation slope is usually the most desirable and it is best to conform to it as much as possible. But in some types of soils and topography—such as rolling, upland areas with soils not deep enough to permit much leveling—it is necessary to irrigate with nonuniform slopes.

Nonuniform slopes cause the water to flow unevenly down the strip checks. Where the grade flattens out, the water will be deepest and will remain longest. To the degree that this occurs, the levees must be reinforced to confine the water to the individual strip checks.

Nonuniform slopes also result in unequal depth of water penetration, a condition which varies with the porosity of the soil. If the soil is porous, the loss of water by deep percolation in the stretches with little slope will be high. If the soil is clay, the steep stretches may not receive sufficient water.

Length of strip check depends on slope and size of stream

It is essential that a strip check be of the proper length in relation to the irrigation slope and the size of the irrigation stream. This will make possible (within practical limits) uniform depth of water penetration from the upper to the lower end of the strip check.

If the strip checks are long, the irrigation slope and irrigation stream small, and the permeability or water intake rate of the soil high, the upper end of the field will receive more water than the lower.

Faster irrigation aids water distribution. Faster irrigation, accomplished by increasing the irrigation slope, using a larger irrigation stream, and shortening the length of the strip check, will tend to correct such faulty water application.

But shortening the strip check is usually better. The best remedy for unequal water penetration often lies in reducing the length of the strip check—a simple matter if the topography and type of soil permit the use of unlined ditches. Strip checks can be shortened by opening up another field ditch across the checks,

and watering the lower end of the field from the second ditch. The extra ditch can be quickly and inexpensively built with an implement similar to the one shown below. Since it can be easily filled in with a 3- or 4-bottom plow or other suitable implement, the ditch need not be an obstruction during harvest.

But if the water must be conveyed to the strip checks by a lined ditch or pipe line, the cost of the new ditch might be prohibitive. In such cases, necessary adjustments can be made by changing the size of the irrigation stream, or, if possible, altering the irrigation slope.

Field conditions affect length. No single figure for the length of the strip check can be cited as ideal under all field conditions. Tables 1 and 2 will help to determine the appropriate length to which the strip checks may be extended when land is first prepared for irrigation.

Irrigation trial runs should next be made, in the manner described on page 22. Then, if the depth of water penetration is found to be excessive, inadequate, or nonuniform with the upper and lower ends of the field, the length of the strip checks can be changed accordingly.

Strip checks may vary from 200 to 2,000 feet in length. Deep, sandy soils should usually be irrigated in strips from 200 to 300 feet long. Clay soils, with a water intake rate of around 0.2 foot per hour, should be irrigated very slowly, and in relatively long strips. With slowly permeable soils, upwards of 2,000-foot runs will result in uniform distribution of the water.

Under ordinary conditions, however, it is advisable to adopt about half that distance, or about 1,000 feet, as the ideal maximum length.

Pay close attention to the water. In border-irrigating, it is necessary to know when the water reaches the lower ends of the strip checks, so that the water may be cut off, or cut back, at the proper time. It is also part of the irrigator's job to kill gophers, to strengthen levees where necessary, and to see that the water entirely covers the strip checks at all points.

A custom made ditcher such as this may be used for shortening strip checks.

Table 1. Tentative Standards for Estimating Unit Flow of Water and Length of Strip Check for Border Irrigated Alfalfa.

Soil profile	Slope	Flow per foot width of strip check		Average depth of water applied*	Strip check		Suggested basis for design
					Width	Length	
	ft. per 100 ft.	g.p.m.	c.f.s.	inches	feet	feet	
SAND	.2– .4	50–70	.11–.16	4	40–100	200–300	Very rapid spread of water, minimum length of strip check and small average depth of water application
60-inch permeable	.4– .6	45–50	.10–.11	4	30–40	200–300	
subsoil	.6–1.0	25–40	.06–.09	4	20–30	200–300	
SANDY LOAM	.2– .4	25–35	.06–.08	5–6	40–100	300–600	Fairly rapid spread of water, short length of strip check and medium average depth of water application
60-inch permeable	.4– .6	20–30	.04–.07	5–6	20–40	300–600	
subsoil	.6–1.0	10–20	.02–.04	5–6	20	300	
CLAY LOAM	.2– .4	15–20	.03–.04	6–7	40–100	600–1000	Fairly slow spread of water, long strip checks and heavy water application
60-inch permeable	.4– .6	10–15	.02–.03	6–7	20–40	300–600	
subsoil	.6–1.0	5–10	.01–.02	6–7	20	300	
CLAY 60-inch + permeable subsoil	.2– .3	10–20	.02–.04	7–8	40–100	1200 +	Slow spread of water, long strip checks, maximum depth of water applied
CLAY ADOBE	.2– .3	2–10	.004–.02	7–8	40–100	1200 +	

* Depends on the available water-holding capacity of the soil. Usually 1-inch depth of water will wet sandy soil 12 inches or more deep; loam soil, 6 to 10 inches deep; and clay soil, 4 to 5 inches deep.

Table 2. Tentative Standards for Estimating Unit Flow of Water and Length of Strip Check for Border Irrigated Pasture.

Soil profile	Slope	Flow per foot width of strip check		Average depth of water applied	Strip check		Suggested basis for design
					Width	Length	
	ft. per 100 ft.	g.p.m.	c.f.s.	inches	feet	feet	
CLAY LOAM 24-inch + over permeable subsoil	0.15–0.6	25–35	.06–.08	2–4	15–60	300–600	Fairly rapid spread of water, short lengths of strip checks
	.6 –1.5	20–30	.04–.07	2–4	15–20	300–600	
	1.5 –4.0	10–20	.02–.04	2–4	15–20	300	
CLAY 24-inch + over permeable subsoil	0.15–0.6	15–20	.03–.04	4–6	15–60	600–1000	Slow spread of water, long strip checks
	0.6 –1.5	10–15	.02–.03	4–6	15–20	600–1000	
	1.5 –4.0	5–10	.01–.02	4–6	15–20	600–1000	
LOAM 6- to 18-inch over hardpan	1.0 –4.0	5–20	.01–.04	1–2	15–20	300–1000	Steep slope, narrow strip checks, depth of water application restricted by substratum

The entire length of the strip check must, therefore, be inspected several times during an irrigation, and the distance should be such that the strip check will be covered by a man walking as often as is necessary.

Width of strip check depends on 4 factors

Width of strip check, another way of saying "the spacing of levees," depends on four controlling factors: the amount of cross slope, the steepness of the irrigation slope, the size of the irrigation stream available, and crop to be grown.

Amount of cross slope. The effect of this has already been touched upon; it has been implied that the strip checks should be of a width which, at successive border lines, would make unnecessary a difference in elevation of more than 0.2 to 0.3 foot. Thus, a cross slope of 1 per cent, or one foot for each 100 feet width of field, would allow a maximum width of strip checks of from 20 to 30 feet.

Steepness of the irrigation slope. Steep irrigation slopes call for narrow strip checks, because the large streams of water required for wide strip checks tend to channelize and cause serious erosion. Thus, for the flattest irrigation slopes—which range from 0.15 per cent to 0.3 per cent—any convenient strip width up to 100 feet or more may be used.

For slopes that range from 0.4 to 0.5 per cent, it is recommended that strips from 20 to 30 feet wide be used. For greater slopes, the maximum width should be from 15 to 20 feet.

Size of the irrigation stream. The amount of water available may limit the width of the strip checks. E.g. if 225 g.p.m. are available for irrigating a soil which requires a unit flow of water of 9 g.p.m. for each foot-width of strip check, the maximum width of the strip check that can be irrigated would be 25 feet.

Kind of crop to be grown. When a crop such as alfalfa or clover is mowed, raked and baled, or threshed, most farm

operators make the width of the strip check correspond to the width of their harvesting equipment. In this way they avoid unnecessary crossing of the levees.

Widths usually start at 40 feet and may be increased by 20-foot increments; or they may be 40, 60, 80, and 100 feet wide. A 40-foot strip check is sufficient for six sweeps of a 7-foot mower, with some allowance for overlap. The increment of 20 feet provides room for three additional sweeps of the mower.

These distances are also practical for other farm equipment.

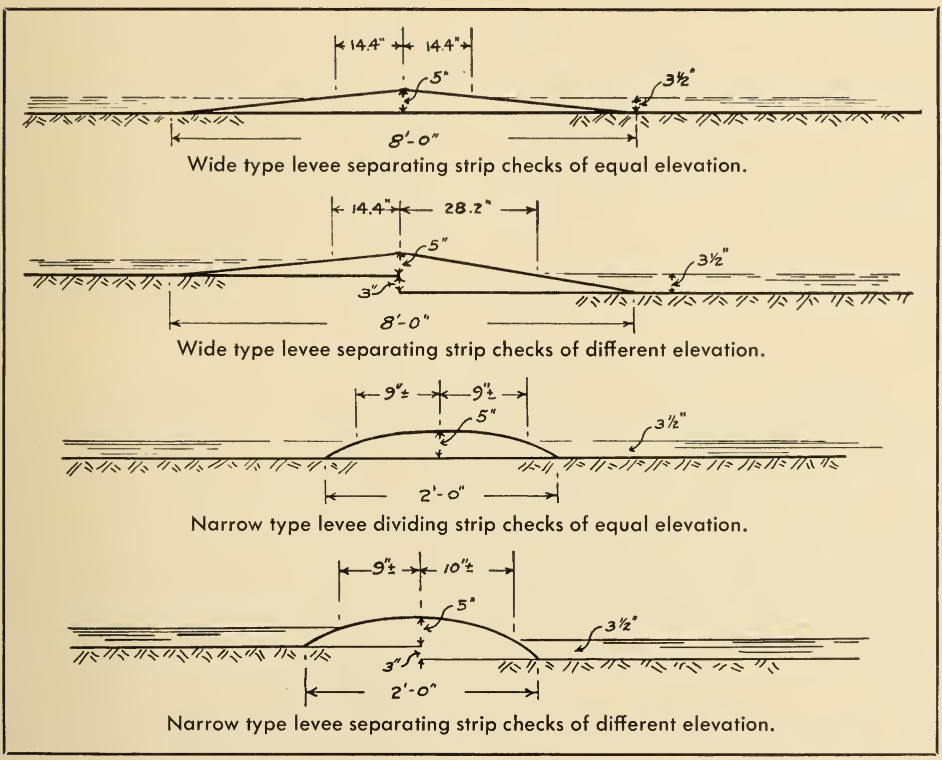
In order to allow machinery to pass from one strip check to another without crossing levees, it is sometimes necessary to discontinue the levees 15 or 20 feet from the lower end of the field. It will still be necessary to cross the levees at the upper end of the field—an operation usually entailing the lifting of the cutting bar.

In some cases this spacing of levees may not be necessary. When the wide, low levee described on page 12 can be used, it will prove less of a hindrance during harvest.

The width of strip checks in irrigated pastures harvested entirely by grazing need not be gauged to accommodate harvesting machinery. Such strip checks may range in width from the generally recognized minimum of 15 feet to the maximum of 100 feet or more. However, if the crop is to be cut for seed occasionally, a minimum of 20 feet is recommended.

Shape of levees depends on 3 factors

Levees should be designed and constructed to meet three requirements: They should confine the irrigation water to the individual strip checks; they should wet through sufficiently to support the crop on the borders; and they should be easy to cross with farm implements in fields harvested with machinery.



The wide, low levee shown in the accompanying drawing illustrates all three. The levee, suitable for use on fields with little cross slope, has sufficient strength and body to prevent its being undermined by the irrigation water. The long, flat side slopes allow the irrigation water in adjacent strip checks to cover the maximum amount of levee surface. If the levees are not too high, they will wet through sufficiently to permit the growing of crops on their surfaces. The gradual, sloping sides and low crest provide an easy crossing for farm implements.

This type of levee is usually about 8 feet wide; 4 to 6 inches in settled height.

If the wide type of levee were used with the maximum cross slope, the water surfaces in adjacent strip checks might be too far apart during irrigation to wet through at the border lines.

Correct use of a narrow levee. Narrow levees are advisable when the cross slope approaches the maximum. On fields requiring little use of machinery, they are adequate.

As the drawing shows, water has a much better chance of wetting through when the narrow levee is used. If water fails to wet completely through the narrow-type levee, only a very narrow strip of dry soil will be left—at best. Such a strip produces no return, and it provides a place for the growth of fox-tail and other undesirable plants. You should note here that borders, to sustain a good crop stand, must be compact and firm.

For close-growing perennial crops, the narrow type of levee has its drawbacks. It offers greater obstruction to the movement of farm machinery across the strip checks than the broad levee, and it does not hold up well under vehicular traffic.

The narrow levee is usually about 2 feet wide; 4 to 6 inches in settled height.

What is the ideal shape for the field?

A rectangularly shaped field with a natural slope, or a graded surface which permits the use of strip checks of equal length, is best.

An extreme case of a badly shaped field would be a triangular one which requires that all strip checks be of different lengths. It is almost impossible to irrigate such a field without waste-water runoff. When the strip checks are of different lengths, constant attention is required during irrigation to wet all of them with the same amount of water, without waste or runoff.

It is possible, though not always practical, for the irrigator to equalize the time that water remains on each strip, and, in the same operation, prevent excessive waste-water runoff from the short strips.

Sometimes the irrigator will cut back the irrigating stream. In this operation, when the water has reached the lower end of the short strips, the stream is reduced to the amount of water being absorbed. The irrigator then allows this stream to run until the longest strip has been irrigated.

This procedure is sometimes followed. Too often, however, because of the irrigator's tendency to save on labor and waste the water, cutting back the stream does not work out.

Occasionally a better solution to the problem will be found in land leveling, perhaps with the relocation of a natural drainage channel. Many ill-shaped fields can be squared up in this manner—although it sometimes proves too expensive to be feasible.

At any rate, the farmer should consider this question when planning land-leveling operations.

Consider the direction of irrigation

In localities having strong prevailing winds, strip checks should be laid out lengthwise with the wind. In order to prevent wind interference during harvest, this point must also be remembered when planning to level the land.

To cut down on unnecessary crossing

of the borders with the harvesting machinery, border-irrigated alfalfa and clover fields are usually mowed, windrowed and baled, or threshed, lengthwise of the strip checks.

If the strip checks lie perpendicular to the wind the windrows will be exposed broadside to the wind action, the crop will roll before a strong wind, and there will be leaf or seed loss. This is a poor arrangement for harvesting seed.

Provide surface drainage

Pasture, especially, should be provided with a means of quick surface drainage. According to *Irrigated Pastures in California,* Circular 125 of the California Agr. Ext. Ser., ground surface should be dry enough for grazing without damage to soil or crop as soon as the plant growth reaches the proper maturity for feeding. Most soils used for pasture are slowly permeable and, unless provision is made for surface drainage, remain wet for long periods between irrigation operations.

Relatively steep slopes of 0.5 per cent or more, with adequate wasteway facilities, are desirable. If the irrigation slope is relatively flat (0.15 to 0.2 per cent) and the soil is of the slowly permeable type, adequate surface drainage can usually be obtained by the use of short strip checks, together with an adequate wasteway across the lower end of the field.

For extremely flat slopes, it is best to construct the borders with a ridger, or a border disk, shown on page 5, leaving the furrow or trough on either side open, to serve as a drain towards the waste ditch.

Avoid runoff, or ponding. It is possible to irrigate alfalfa without runoff or ponding by either cutting back or closing off the irrigation stream, when the water approaches to within about 100 feet of the lower end of the strip check. Allowance must be made for the fact that the irrigator may fail to cut off the flow at the proper time.

Strip checks should, if possible, terminate in a wasteway connected with some type of drainage channel. If this is not feasible, ponding may be relieved by letting the water spread out widely on the surfaces not yet irrigated, at the lower end of the field.

The attempt to avoid ponding provides another reason for discontinuing borders 15 or 20 feet short of the full length of the field, as mentioned on page 10. Runoff from an irrigated strip check will thus flow into, and up adjacent strips that have not yet been irrigated. When it is time to irrigate the adjacent strips, the irrigation stream is cut off sooner than usual to allow for the already wetted section at the lower end. It is sometimes desirable to reservoir the waste water and pump it back to the head ditch for reuse.

Ponding, a result of poor leveling or failure to provide drainage.

THREE WAYS TO CONSTRUCT STRIP CHECKS . . .

cross checking, ridging, single operation

Cross checking means scraping the entire field at right angles to the proposed strip checks, and dumping sufficient earth along each border line to make the levees. Before this is done, the field should be plowed or disked; after it is done, the strip checks should be smoothed lengthwise.

The cross checking method involves these steps: staking, marking, cross checking, plowing, and shaping the borders.

Staking. Two men should measure off the space between levees on opposite sides of the field. Measurements should be accurate, because the strip checks should be of the same width if they are to irrigate evenly. Laths, or long stakes, are driven into the ground to mark the end of each levee. The stakes are flagged so that they may be seen from one end of the field to the other.

Marking. Using a small, general-purpose tractor, with shovel or chisel attached, the operator makes a shallow furrow or groove between the stakes at the end of each proposed levee. Clearly visible marking greatly facilitates the proper alignment of the levees.

Cross checking. This means of forming the levee dumps is important enough to lend its name to the entire operation. It is accomplished by scraping backwards and forwards *across* the field, perpendicular to the proposed strip checks, and dumping the scraper at each border line.

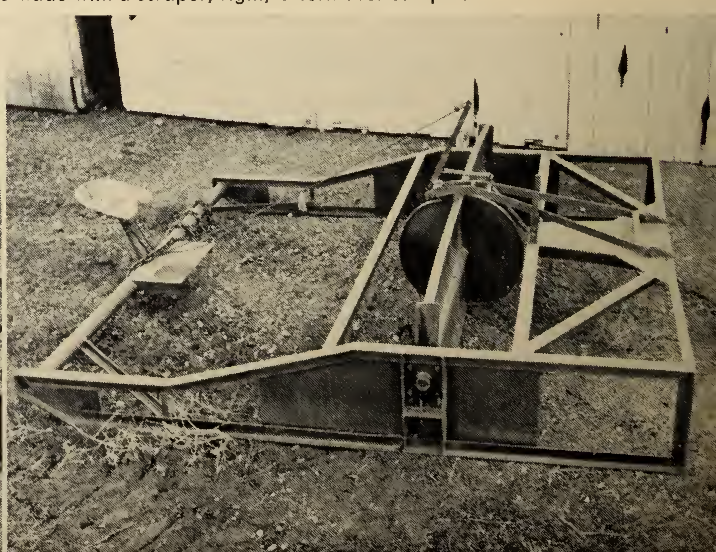
One operator, running either a hydraulically dumped scraper or a turn-over scraper powered by a D-4 tractor or its equivalent, is usually needed.

The turn over scraper is a home-made device which may be unknown in some communities but is favored by many operators. As the illustration shows, the scraper blade has two cutting edges, revolves 180° to dump, and then returns to the scraping position. This is considered an easy and accurate method of dumping. Its disadvantage is that it does not remove excessive cross slope, when this condition is met.

Why remove excessive cross slope? If the cross slope is 0.2 per cent or less, and the border interval is 40 feet or less, there is no need to take the side slope out at the border lines. To make the border dumps, one can scrape the field uniformly with a turn-over scraper.

But if the cross slope exceeds 0.2 per cent, some cross leveling of the strip checks will be necessary. This can be done during the cross-checking operation, by tapering the depth of scraping from the

Left, levee dumps made with a scraper; right, a turn-over scraper.



Left, plowing levees with a 5-bottom plow; right, shaper for making borders.

high to the low side of each strip with the hydraulically dumped scraper. Skill on the part of the operator is essential.

Plowing. In border construction, plowing means working the levee dumps down into a rough ridge. Two trips (one down and one back) on either side of each row of dumps, with a 5-gang plow set to throw the soil to the center, leave ridges uniform enough to be shaped with other implements.

Shaping the borders. Any one of a number of border machines can shape, but many farm operators prefer to use the homemade device illustrated. The machine consists of two tools mounted in the same frame, containing an open-end V, or ridger, which crowds the soil into a peaked levee. A V, pointing forward, is pivoted at the end of each leg so that the point can be adjusted up or down.

The machine controls the height of the levee, and makes the straight, flat-sloping sides desirable in a field where harvesting machinery will be used. It can be pulled by a D-6 tractor or the equivalent.

The road grader or a conventional border shaper will be equally effective.

How long should this operation take? The time consumed by cross-checking depends on the length and spacing of the levees. A levee spacing 40 feet wide will require more time than one of 80 feet, since twice the length of levee

Another type of shaper for making borders. This one makes wide, flat-sided levees.

Table 3. Detailed requirements* and cost for constructing, by cross checking, strip checks on a 40-acre square tract of land.

Operation	Number of men	Hours required	Man-hours	Equipment	Tractor-hours	Recapitulation	Cost
Staking	2	2	4			4 man-hours at $1.00	$ 4.00
Marking	1	4	4	Two-plow size tractor with one shovel or chisel	4	4 tractor-hours with driver at $4.00	16.00
Cross checking	1	20	20	D-4 or equivalent and turn over scraper	20	20 tractor-hours with driver at $5.00	100.00
Plowing	1	3	3	D-4 or equivalent and 5-gang moldboard plow	3	3 tractor-hours with driver at $5.00	15.00
Shaping	1	4	4	D-6 or equivalent and shaper	4	4 tractor-hours with driver at $6.50	26.00
Floating	1	12	12	D-4 or equivalent and float	12	12 tractor-hours with driver at $5.00	60.00
						Total cost	$201.00
						Total cost per acre	5.00

* Not including precultivation of the field.

is involved. Because less time is lost on turns, less time is required for long strip checks than for short ones.

On a square, 40-acre tract with levees 40 feet apart, the approximate time in man and machine hours needed for each operation is shown in table 3.

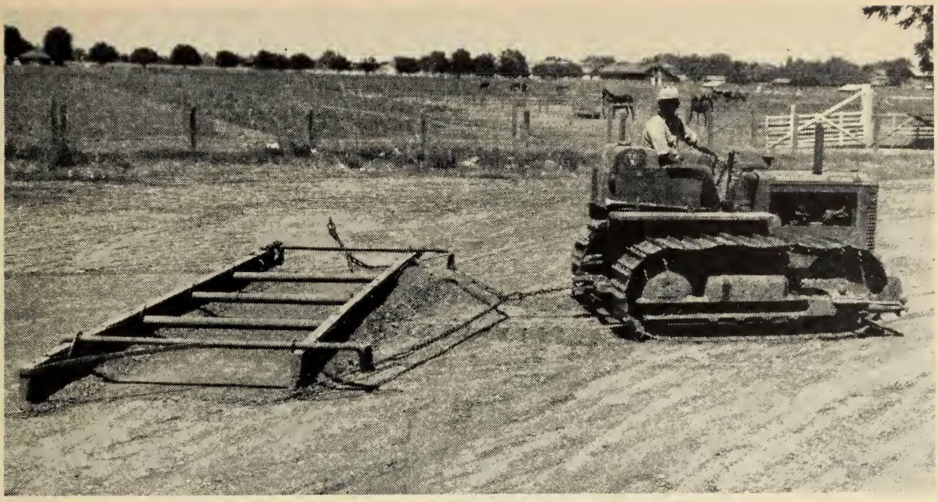
After the levees have been completed, the surface of the strip checks may need to be smoothed lengthwise, in order to remove small irregularities on the soil surface made during the cross checking, plowing, and shaping operations. This is usually done by drawing the strip check drag (shown on page 17) lengthwise of the strip checks, with the sides of the drag parallel to the levees.

Ridging means forming the levees with a border disk or a ridger (shown on page 5) in the same manner as that described for constructing temporary levees. Levees in this instance are usually more substantially built.

The ridging method involves these steps: Staking, marking, building levee foundations, ridging, and leveling strip checks.

Staking and marking have already been described above in the discussion of cross checking.

Building levees. A foundation for the levees is usually provided for permanent-type strip checks by plowing on either side of each border line, and throw-



A strip check drag used for individual leveling of strip checks.

ing the soil to the center. Next, the border disk or the ridger is used to form levees of the narrow, rounded type that are desirable if there is much difference in elevation between adjacent strip checks.

At this point, the operator finds that depressions have been left on either side of each levee. Unless these depressions are needed as surface drains for very flat land and heavy soil, they should be removed by the crosswise leveling of each strip check.

Leveling strip checks may be accomplished in two ways. First, the necessary amount of soil may be graded towards the levees and away from the center line of the strips, using a road-grader operating lengthwise of the strips.

Or, second, a steel-shod strip check drag of the proper size, weight, and hitch may be used. This implement is drawn lengthwise of the strips, with one corner directed forward, so that the high ground in the middle of the strips is scraped off,

A machine that is used for making strip checks by the single operation method.

Table 4. Requirements and costs for constructing by ridging, strip checks with levees 40 feet apart on a 40-acre square tract.

Operation	Number of men	Hours required	Man-hours	Equipment	Tractor-hours	Recapitulation	Cost
Staking	2	2	4			4 man-hours at $1.00	$ 4.00
Marking	1	4	4	Two-plow size tractor with one shovel or chisel	4	4 tractor-hours with driver at $4.00	16.00
Plowing levee foundations	1	3	3	4-D size tractor and 3-gang moldboard plow	3	3 tractor-hours with driver at $5.00	15.00
Ridging	1	3	3	D-4 size tractor and ridger	3	3 tractor-hours with driver at $5.00	15.00
Leveling with 12-ft. drag	1	16	16	D-4 size tractor and 12-foot drag	16	16 tractor-hours with driver at $5.00	80.00
						Total cost	$130.00
						Cost per acre	3.25

and worked over to the low area next to the levee. First one side of the check is dragged, then the other; thus, the soil is worked away from the middle and towards the sides.

With either method, several trips along each strip may be necessary.

Is ridging expensive? Except for necessary plowing or disking of the field—which may be charged to expenses involved in seedbed preparation—the requirements and costs of the ridging method of constructing permanent strip checks are shown in table 4.

Single operation means the simultaneous forming of levees, and the crosswise leveling of the strip checks. Some preliminary plowing or disking of the soil will be necessary before the operation is begun.

Special implements are needed to do the job. Essentially, these implements consist of a V-shaped scraper blade, equipped with an indicator and controls for keeping the blade level. The scraper blade must reach from inside edge to inside edge of adjacent levees.

In the implement shown, the blade is 12 feet wide. The implement makes a strip check 15 feet wide from the center line of the border on one side, to the center line of the border on the other side. This is the common width of strip check used for irrigating pasture on land having steep irrigation slopes and/or side slopes.

Sometimes an extension of 3 feet to each end of the 12-foot blade is provided, making possible the construction of strip checks with an over-all width of 21 feet. The blade, which rests on roller bearings, is lifted and kept level by hydraulic controls. Its frame is bolted rigidly to the frame of the tractor which pushes it.

From his seat on the tractor (usually

of 4-D size) the operator watches a spirit level or a gauge which works on the pendulum principle. When the indicator shows that the scraper blade has varied from level, the operator moves the hydraulic control until the indicator returns to level. Thus, the blade is kept level and, likewise, the strip check.

When the end of the strip check is reached, the blade is lifted for turning. As soon as the operator is in position to start another strip check, the blade is again let down. As each strip check is made, the next one is marked by a small wheel or shovel attached to a rod protruding from the side of the tractor.

What are the advantages of this method? This equipment is usually made and owned by contractors who handle the preparation of land for irrigation. They claim that the equipment is capable of taking out up to 2 per cent side slope, and of completely bordering 5 acres of land per hour.

A wide-bladed road grader is sometimes used in the same manner.

CONTROL IRRIGATION WATER

by pipe line, or by ditch structures

There are two kinds of structures for controlling irrigation water. When it is necessary to raise the level or water pressure in the field head-ditch or pipe line, checks, dams, or gates are used to force the water to flow on the strip checks. To release the water for irrigation, border gates; or siphons through or over the ditch bank; or alfalfa valves set at intervals along the pipe line are used.

What is a pipe line structure?

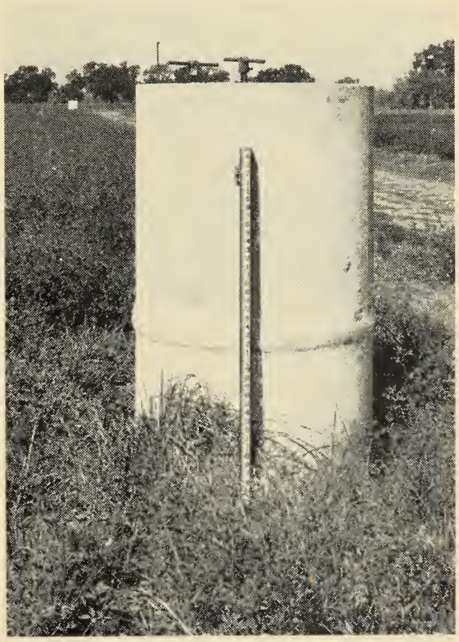
When it is necessary to increase the head or water pressure, metal gates which will check or stop the flow of water are installed in standpipes placed in the pipe line at the required intervals.

Alfalfa valves. These are outlets for turning the water on the field. They are cemented to the tops of riser pipes, which are placed in the pipe line at intervals of every border or every other border, so that each valve may serve one or two strip checks. To avoid erosion, the valves must be set slightly below the ground surface.

Hydrant distributor head. This is a convenient device for dividing the flow of water between adjacent strip checks. It is portable, and can be quickly installed by slipping it over the rim of the valve, which it must fit snugly.

What is a ditch structure?

Permanently installed checks, or portable canvas dams are used to raise the



A typical standpipe for a concrete pipe line irrigation water supply.

An alfalfa valve without distributing head.

Distributing head for an alfalfa valve.

water level in head ditches. Water is released for irrigation either through permanently installed border gates that are set in the ditch bank; portable siphons laid over the ditch banks; or simply by cuts in the ditch bank temporarily left open.

Check gates and border gates. These are usually installed in permanent ditches which are grazed or sprayed for control of vegetative growth.

Canvas dams. Since farm implements must sometimes be used for cleaning the ditches of vegetative growth and sediment, it is desirable to keep ditches free of permanent structures. In such cases, the water level in successive ditch sections is raised by means of two canvas dams, set alternately, one below or one above the other. The water is then either siphoned over the ditch bank or taken out through open cuts.

The design and construction of pipe line structures and ditch structures are fully discussed in *Farm Irrigation Structures*, Exp. Sta. Cir. 362.

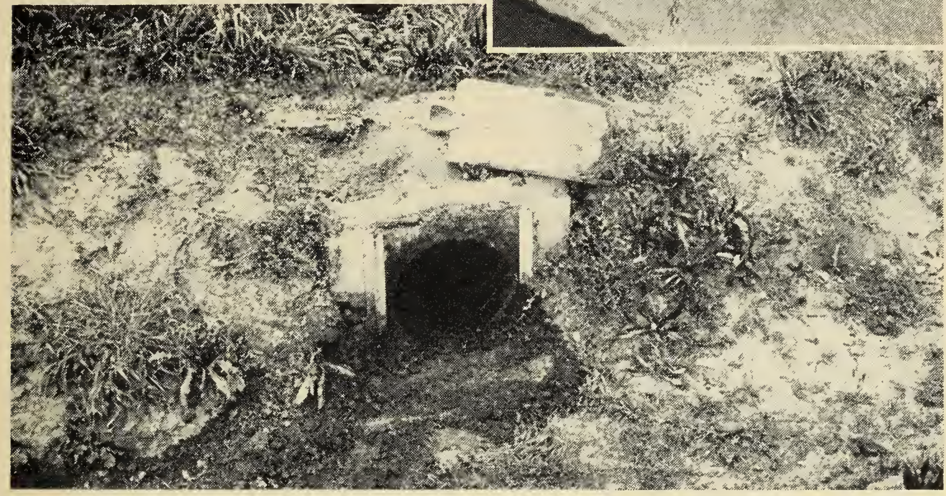
A wooden check gate is permanent.

Canvas dams are portable with ease.

THESE . . .

are some of the structures needed to help control the flow of irrigation water—to get it where it is needed, in quantities that will be effective.

Right, a flume type border gate for letting water out of a concrete supply ditch and into the strip check.



Above, mole type of border gate for taking water from supply ditch. Below, portable siphons used to take water over the side of the ditch and into the strip checks.

IRRIGATION OPERATIONS . . .

here are some essentials

Cutting off the irrigation stream

After the stream is cut off at the head ditch, the water continues to move down a check. If water is allowed to reach the lower end at, or before, the time at which it is cut off, and there is no waste ditch to take care of the runoff, it will pond at the lower end.

Some ponding is bound to occur in border irrigation, but excessive amounts should be avoided. Ordinarily, the irrigation stream should be cut off or reduced when the water is within 100 feet of the lower end; but in some instances up to 300 feet must be allowed.

Cutting back the irrigation stream

Because of differences in the length of time the water is in contact with the soil, there is always some unequal penetration of water from the upper to the lower ends of the strip check. If, in one operation, one could apply and maintain a shallow depth of water over the entire strip check for the required time, the depth of water penetration would be uniform and sufficient. By cutting back the irrigation stream, a procedure referred to on page 12, it is possible to approximate this ideal result.

By means of a large irrigation stream, water is quickly forced to a point within about 100 feet of the lower end of the strip check before much difference in depth of water penetration at the upper and lower ends can occur.

If the soil is not wetted deeply enough, the stream is cut back to the size which will maintain a shallow depth of water from one end of the strip check to the other, without causing runoff.

A rule of thumb. Reduce the flow to from ½ to ¾ of the original amount. Then, continue to irrigate with the smaller stream until the soil is wetted to the required depth.

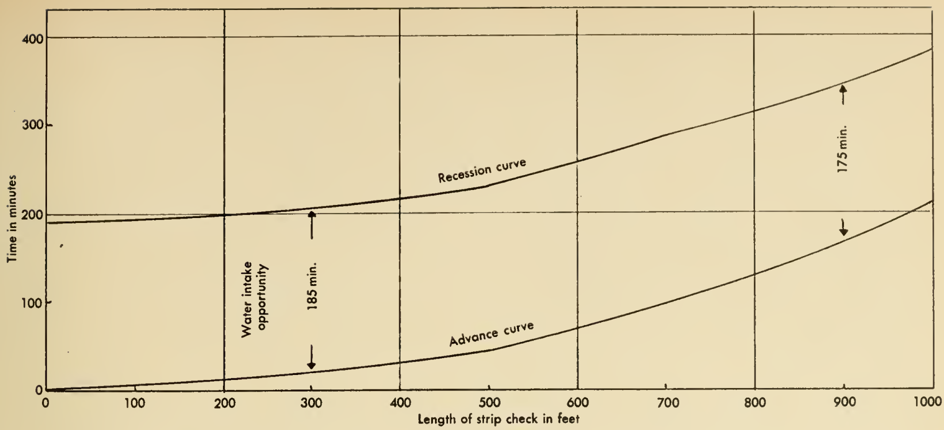
Trial field runs determine unit flow and length of check

Field trial runs consist of irrigating several strip checks with different-sized streams of water, and determining the length of time the water remains on each successive 100-foot length of strip. The length of the strip check and the size of the irrigation stream are the two changeable factors which allow the water to remain an equal, or nearly equal, length of time on each 100-foot length of strip. Properly combined, these factors produce uniform or nearly uniform application of water.

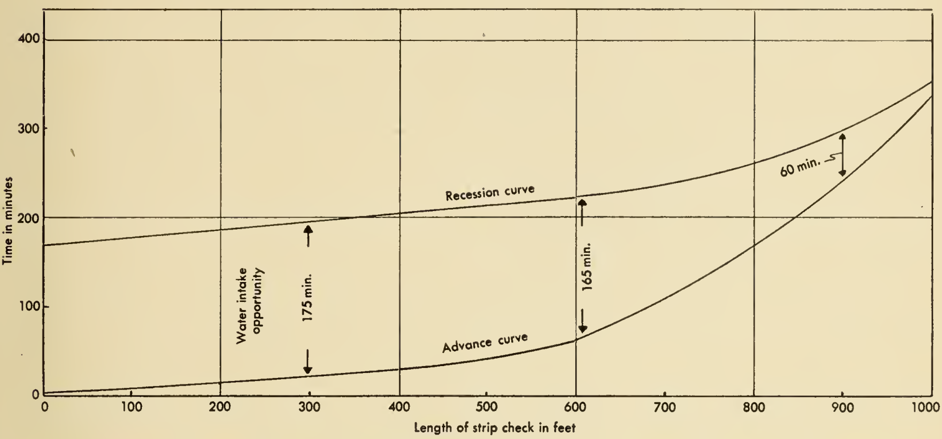
A change in soil, or a material departure from a uniform slope, may cause unequal water application—no matter what size of irrigation stream or length of strip check is used. Therefore, before trial field runs are warranted, the land should be examined with these soil characteristics in mind.

How to make a trial field run. Starting at the head ditch, stakes are set at 100-foot intervals along one of the levees within the area selected for the test. Different-sized streams of water are turned into three or more adjacent strip checks. For strip checks 40 feet wide, and clay soil, 600 g.p.m. (15 g.p.m. unit flow, table 1) is estimated to be the stream of the proper size.

Three streams, one 600 g.p.m., one greater, and one smaller, might be used for the test. The advances of the three streams along the strip checks are timed until they reach each stake. As each stream reaches a point within about 100 feet of the lower end of the field (or any other distance it might be expected to cover without additional flow from the



Graph shows nearly equal water intake opportunity for the whole length of a strip check.



This shows nearly equal water intake opportunity for first 600 feet of a 1000-foot strip check.

head ditch) the border gate is closed so that no more water can enter the strip check.

Now, note the "intake opportunity time." This is the lapse of time from when the water arrives at each stake until it disappears, or the length of time that water standing on the ground has an opportunity to enter the soil. As long as the water intake opportunity along the successive 100-foot sections of strip check remains the same, there is equal penetration and uniform distribution of water.

Plot the results, as shown on the accompanying graphs. In the first graph, the recession curve is nearly parallel to the advance curve, indicating that all of the stations have about the same intake opportunity. The second graph shows the recession curve as being nearly parallel to the advance curve up to 600 feet, but beyond that point the two curves converge. In this case, it is indicated that uniform distribution of water occurs only in the upper 600 feet of strip check.

Has a sufficient depth of water been applied? The water must wet the soil throughout the plant root zone. The depth of water penetration can be measured by using a metal probe or a soil auger.

Calculate the depth of water applied according to the method described in the box on page 24.

HOW TO CALCULATE WATER APPLICATIONS

There is a rule of thumb for checking the depth. One inch of rainfall will wet soils which are shown to be dry by the condition of the crop, as follows:

Sandy soils . . . 12 inches or more in depth
Loam soils . . . 6 to 10 inches in depth
Clay soils . . . 4 to 5 inches in depth

The depth of water that is applied may be calculated for the various units in the following ways:

$$\text{Average depth in inches} = \frac{\text{Cubic feet per second} \times \text{hours stream is used}}{\text{Area of strip check in acres}}$$

$$= \frac{\text{Gallons per minute} \times \text{hours stream is used}}{450 \times \text{area of strip check in acres}}$$

$$= \frac{\text{Southern California Miner's inches} \times \text{hours stream is used}}{50 \times \text{area of strip check in acres}}$$

$$= \frac{\text{Statute Miner's inches} \times \text{hours stream is used}}{40 \times \text{area of strip check in acres}}$$

Example: What is the average depth applied to a ½-acre strip check in three hours by using a stream of 450 gallons per minute?

$$\text{Average depth} = \frac{450 \times 3}{450 \times \frac{1}{2}} = 6 \text{ inches}$$

If loam soil is being irrigated, a 6 inch depth of water could be expected to wet the soil to a depth of 36 to 60 inches. Following the irrigation, the resulting depth and uniformity of water penetration should be carefully checked with a soil auger or probe.

The number of hours a stream must run may be obtained from another arrangement of the same factors as follows:

$$\text{Hours stream will be used} = \frac{\text{Average depth in inches} \times \text{area of strip in acres}}{\text{Cubic feet per second}}$$

$$= \frac{\text{Av. depth in inches} \times 450 \times \text{area of strip in acres}}{\text{Gallons per minute}}$$

$$= \frac{\text{Av. depth in inches} \times 50 \times \text{area of strip in acres}}{\text{Southern California Miner's inches}}$$

$$= \frac{\text{Av. depth in inches} \times 40 \times \text{area of strip in acres}}{\text{Statute Miner's inches}}$$

Example: How many hours must a stream of 450 gallons per minute be applied to a ½-acre strip check to wet a clay soil 40 inches deep?

According to the rule of thumb it requires from 8 to 10 inches of depth of water to wet clay soil to a depth of 40 inches.

Then,

$$\text{Hours stream will be used} = \frac{8 \times 450 \times \frac{1}{2}}{450} = 4 \text{ hours}$$

$$= \frac{10 \times 450 \times \frac{1}{2}}{450} = 5 \text{ hours}$$

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